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AUTOMATION, ROBOTICS, AND INFLIGHT TRAINING  
FOR MANNED MARS MISSIONS

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ABSTRACT

The automation, robotics, and inflight training requirements of manned Mars missions will be supported by similar capabilities developed for the Space Station program. Evolutionary Space Station onboard training facilities will allow the crewmembers to minimize the amount of training received on the ground by providing extensive onboard access to system and experiment malfunction procedures, maintenance procedures, repair procedures and associated video sequences. Considerable on-the-job training will also be conducted for Space Station systems management, mobile remote manipulator operations, proximity operations with the Orbital Maneuvering Vehicle (and later the Orbital Transfer Vehicle), and telerobotics and mobile robots. A similar approach could be used for manned Mars mission training with significant additions such as high fidelity image generation and simulation systems such as holographic projection systems) for Mars landing, ascent, and rendezvous training. In addition, a substantial increase in the use of automation and artificial intelligence for systems management and in the use of automation and robotics for hazardous and tedious tasks would be expected for Mars missions. Mobile robots may be used to assist in the assembly, test and checkout of the Mars spacecraft, in the handling of nuclear components and hazardous chemical propellant transfer operations, in major spacecraft repair tasks which might be needed (repair of a micrometeoroid penetration, for example), in the construction of a Mars base, and for routine maintenance of the base when unmanned.

INTRODUCTION

The manned Mars missions will require a substantial implementation of automation, robotics, and inflight training capabilities. The Space Station program is planning to incorporate a considerable amount of automation and robotics(A&R) into the Station and platform systems. In addition, extensive onboard training capability is being planned. Space Station program development and later operations should provide a good "test bed" for assessing Mars mission requirements for A&R and inflight

training. The need for advanced development activities can be based on these assessments.

#### SPACE STATION AUTOMATION AND ROBOTICS PLANS

The Space Station automation and robotics (A&R) implementation is being emphasized in part because of the special mandate Congress has given to NASA. Congress has asked NASA to use the Space Station program to advance the state-of-the-art in application of A&R. In addition, NASA will give emphasis to A&R that will also support the needs of U.S. industry. NASA will brief industry and user representatives on the preliminary plans for A&R technology implementation and solicit comments and suggestions on these plans.

A draft of A&R priorities based on the needs of Space Station users has been developed (Ref 3). Later, a preliminary list of A&R technologies being considered for implementation in the Space Station program will be generated for user and U.S. industry review. Congress has provided additional funding (augmented funding program) to enable the development of a telerobotic system or robotic servicer. As part of this A&R development activity, NASA is evaluating plans for ground and flight demonstrations aimed at the development of the Initial Operating Capability (IOC) Station and the growth phase.

#### SPACE STATION FLIGHT TRAINING AND SIMULATION PLANS

The Space Station program has as a goal an evolution from extensive ground training to a minimal of ground training and extensive use of onboard training facilities and on-the-job training. The onboard training facilities should be capable of using the same computer disks used in ground training, with the exact same crew interfaces. Crewmembers with extensive ground training or previous Space Station experience will conduct on-the-job training, as required, for other crewmembers.

Only a select number of system and experiment malfunctions will be trained on in ground training facilities. The onboard training system will be capable of storing malfunction diagnostic procedures, repair procedures and video demonstrations of repair tasks for a very large group of potential malfunctions and contingencies. The training system may utilize voice actuated commands, optical disks, expert systems and artificial intelligence for interactive training.

The evolutionary Space Station onboard training system may be capable of placing any CRT terminal into an off-line training mode. The actual flight software and current systems parameters statuses can then be used in conjunction with selected malfunctions for training on malfunction procedures. Integrated contingency simulations (involving one or two crew members and ground controllers) for fire, micrometeoroid penetration, release of toxic gases in the Station atmosphere, major system failures and collisions of vehicles would be conducted infrequently. The integrated simulations will keep the crew proficient on quick reaction procedures and will assist in verifying procedure changes uplinked from the ground. An occasional full-up "fire drill" would be conducted for the entire crew.

Training on the Mobile Remote Manipulator System, Orbital Maneuvering System, and EVA operations would be conducted primarily on the ground. On-the-job training would be used to supplement the ground training.

#### MARS SPACECRAFT ASSEMBLY AND CHECK OUT

##### Automation and Robotics

The Orbital Maneuvering Vehicle with a smart front end and the Orbiter or Servicing Platform Remote Manipulator System will be the primary means for assembling major components of the manned Mars Spacecraft. The connection of power, fluid, and data lines and the connection and deployment of smaller structures would require the use of Space Station EVA crewmembers. A combination of special EVA crewmembers dedicated to Mars spacecraft assembly and mobile robots (with telerobotics capability) will likely be used for these tasks. (See Figure 1).

The handling and checkout of nuclear power and propulsion systems before and after the first mission and other hazardous operations may necessitate the use of a mobile robotics capability which exceeds the capability of the OMV smart front end. A multi-arm robot which can grasp a structure and maintain an arbitrary position may be needed. The robot should have multiple sensors including vision in the visual and infrared range, vibration sensitivity (from 1 to 100 Hz, for example), and a laser ranging and attitude system.

Assembly and repair operations will require a versatility in manipulative tools for a mobile robot including power rotating

# SERVICING PLATFORM AND MOBILE ROBOTS FOR MANNED MARS MISSION SPACECRAFT ASSEMBLY

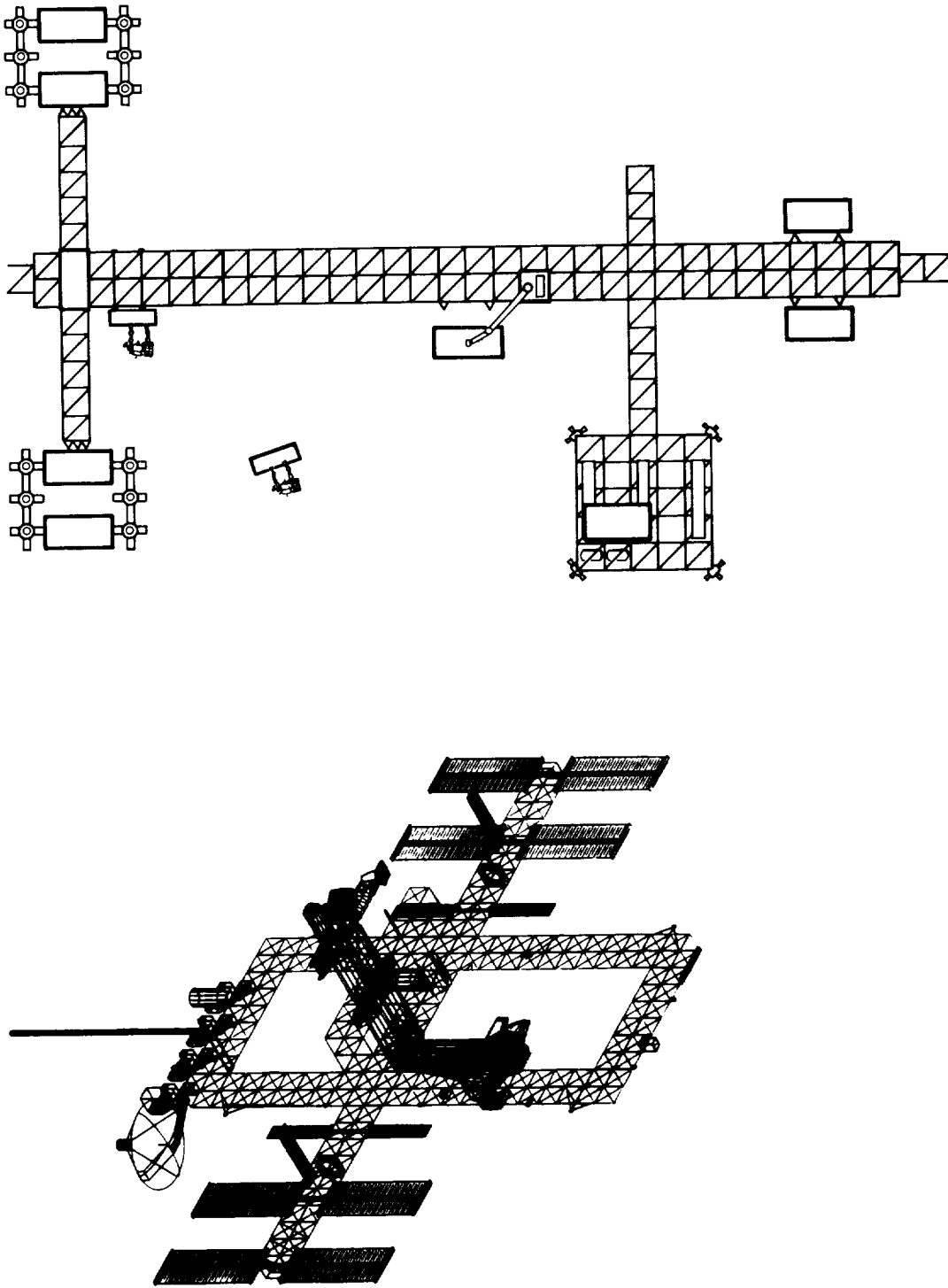


FIGURE 1

tools (angular momentum compensated tools), grasping end effectors, push and pull end effectors, and possibly a laser holographic diagnostic system for the detection of structural and surface faults. Extensive attitude control and translation capability for free flight maneuvers and small payload ferrying activities will be required.

#### Inflight Training and Simulation

During the assembly and checkout phases, the Space Station and later the Mars Mission Modules should have onboard training capability which supports the review of malfunction and repair procedures which may be required to overcome a problem which develops. Video presentations should be available for those problems which have a reasonably high probability of occurrence.

Malfunctions which occur during a checkout phase with a critical system such as a nuclear power system could require a crewmember to stop and review malfunction procedures associated with the new system configuration. This capability to review malfunction procedures should be available at the terminal being used for that portion of the checkout procedures.

As a goal, the Space Station will be designed such that failures in non-critical systems could be diagnosed by expert system software and, in some cases, a switch to a backup system could be executed without a crewmember's involvement. Depending on the type and frequency of the fault, the crewmembers could be immediately notified by an alarm or computer voice generation system. Criteria will have to be developed which help crewmembers determine when an expert system or artificial intelligence software can be relied on to handle a new system configuration or new system performance.

#### INTERPLANETARY OUTBOUND AND INBOUND ACTIVITY

##### Mars Spacecraft Automation and Robotics

Nominal spacecraft systems management should be conducted by expert systems and/or artificial intelligence software. Malfunctions and degraded performance trends should be identified and tracked by automated systems software. As a minimum, recommendations for corrective actions should be made by the software.

Criteria will have to be developed for determining the conditions and systems' types for which the expert or artificial intelligence

systems would be allowed to take independent action. For certain emergency situations, it may be very helpful for the system to take immediate action, for example to minimize the impact of a fire.

For checks of external structures and external repairs, some form of mobile robotics may be required. Consideration should be given to providing a portable laser system for use in surface inspection and minor welding tasks. For external checks of nuclear components, remote viewing by an EVA crewmember with a Manned Maneuvering Unit may not be effective. A mobile robot which is stored outside could be used for a variety of purposes including the investigation of micrometeoroid hits (detected by the robot's sensors or other sensors) and the repair of damaged areas, if required.

#### Mars Spacecraft Inflight Training and Simulation

The onboard training facility must be capable of supporting a great range of malfunction and repair training. Video presentations recorded during ground construction and checkout activities should be available for playback to support training using interactive expert system or artificial intelligence software. Special video and digital training materials should be available to provide training in crewmember fields-of-expertise, which may be related to experiments being conducted during the interplanetary phases or during Mars surface activities.

The training system should support procedures and malfunction training for inflight scientific experiments and technology demonstrations. Training for repairs of artificial intelligence and robotics systems would also be provided.

#### MARS ORBIT INSERTION, LANDING, LIFTOFF, AND RENDEZVOUS

##### Mars Spacecraft Automation and Robotics

Automation (and artificial intelligence) will be used substantially for systems' management and flight control for the Mars landing, ascent, and spacecraft rendezvous phases. Contingencies associated with these phases can be addressed by artificial intelligence software but they must also be integrated with pilot assessments as well.

The Mars Excursion Module or landing module may use techniques such as aerodynamic braking and other active flight control processes which will require the use of expert systems. The expert system may use laser ranging system navigational data as part of its logic processes.

### Inflight Training and Simulation

Crew training on Mars landing, ascent, and rendezvous phases will be a primary focus of inflight training and simulation capabilities. Training on these phases could be accomplished in the Mars Excursion Module (MEM) if EVA access is not required to enter the Module.

High fidelity simulations could be accomplished by the use of holographic image projection systems which would project out-the-window views onto to the windows of the MEM. The same system could be used to provide video images for closed circuit TV screens to simulate external viewing of TV cameras. Off-line training modes could be used with MEM CRT terminals, MEM software and other controls and displays to provide training on various malfunctions and contingencies.

To use the MEM in a training mode will require redundancy in the safeguarding of the flight software to insure that simulated faults do not affect the actual flight software. Backup computers and software might be used for the training mode to provide the additional safeguarding.

Lower fidelity training for these phases could be accomplished using flight type controls and displays and software at a location in a Mission Module. Even for a largely automatic system it will be necessary to conduct extensive inflight training for landing and liftoff phases. Periodic training should be conducted throughout the outbound leg for these phases with more extensive training conducted during the 3 weeks prior to Mars orbital insertion.

### MARS SURFACE ACTIVITIES

#### Automation and Robotics

A mobile robot would be very useful to have on the surface and could be used to assist in Mars base construction tasks, maintenance and repair of nuclear power systems, external tasks required during periods of high solar flare radiation, experiment setup and deployments, area reconnaissance and Mars base management during the unmanned period. (See Figure 2). Other robotics would be useful on a Mars rover for sample collection and remote exploration using telerobotics.

Telerobotics modes for the mobile robot might enable many Mars base management tasks to be conducted during the unmanned phases including some repairs. Automation would be expected for the base systems

# HUMANOID ROBOT ON MARS CONTROLS LANDING SEQUENCE OF UNMANNED LOGISTICS TRANSPORT

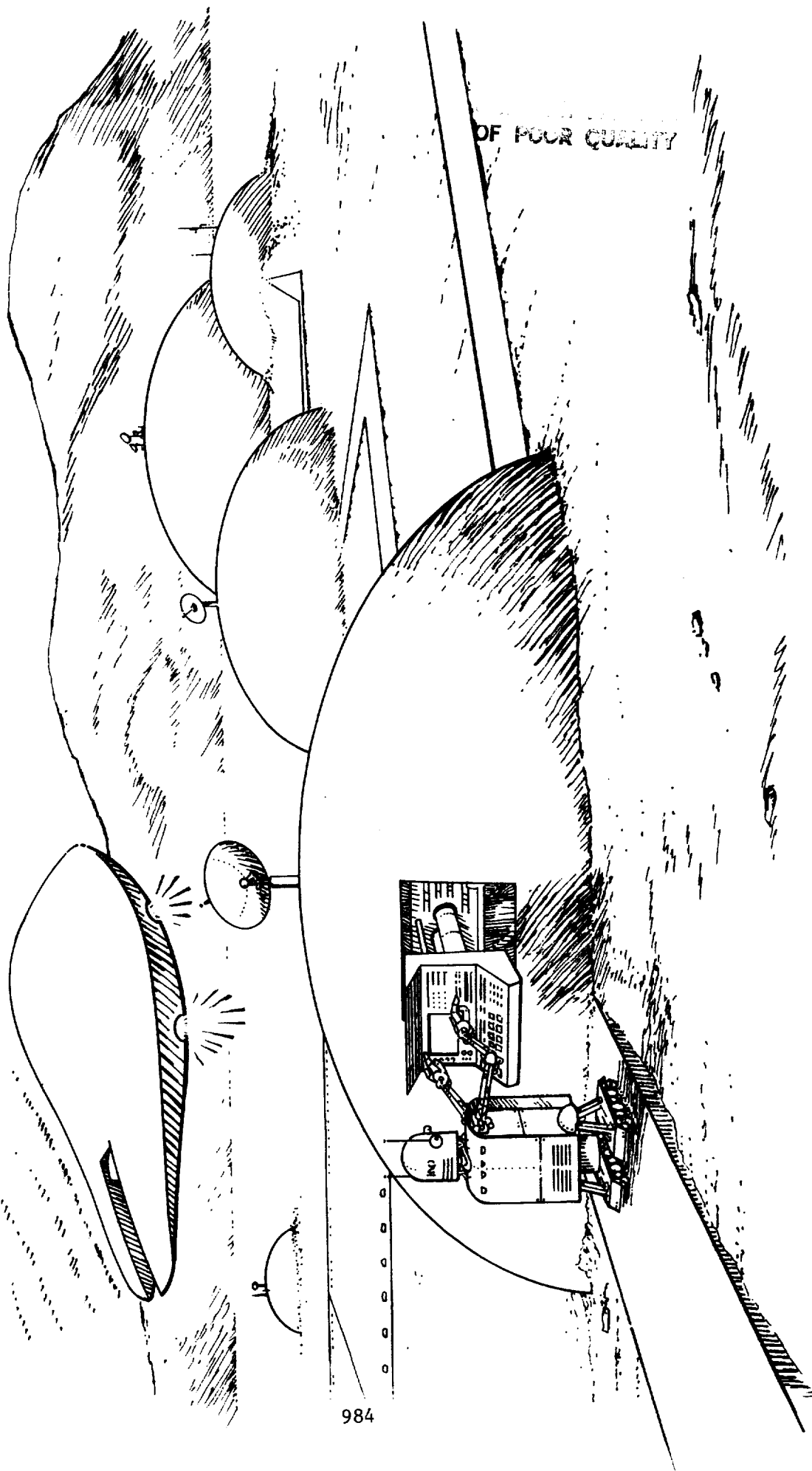


FIGURE 2



management similar to that used on the Mars spacecraft. Considerable attention should be given to the possible use of automation and robotics in support of surface activities. Performance and cost trade studies for Mars landing craft and base systems are required to insure that robotics can be integrated where beneficial. These studies should consider a 10 to 30 year Mars base development plan.

#### Inflight Training and Simulation

Training on the surface would include training for ascent and rendezvous. Surface stay times would be long enough in almost all cases to warrant additional crew training. If a MEM, built in holographic image generation and simulation system is available, then the same system used prior to landing can be used for ascent and rendezvous training.

If the training system can not be integrated in this manner or if the stay time is relatively short, then special off-line CRT displays could be used to review key contingencies and the nominal ascent activities. A surface training system should be available for the MEM and/or Mars base which could be used to call up system and experiment malfunction and repair procedures for review. Some video presentations of repairs should be provided also.

#### EARTH ORBIT INSERTION AND SPACE STATION RENDEZVOUS

##### Mars Spacecraft Automation and Robotics

The Mars spacecraft should utilize a laser ranging and positioning system for rendezvous with the MEM, and rendezvous with the Space Station upon return, and subsequent station-keeping. This data should be used by onboard expert systems to verify and maintain the relative position of Mars spacecraft and the MEM and the Space Station and the Mars spacecraft.

##### Mars Spacecraft Inflight Training and Simulation

Some nominal and contingency training will be required to support Earth orbital insertion and Space Station rendezvous. Visual imagery would be helpful for final approach phases but is not mandatory.

Malfunction or contingency training should emphasize any area where systems failures or performance degradations have been substantial during the flight. Simulations in the off-line training mode will help assure that there are no hidden problems in rendezvous and transfer procedures.

#### CONTINUING STUDY RECOMMENDATIONS

- o Identify and prioritize potential Manned Mars Mission A&R requirements.
- o Identify Space Station A&R activities which should be monitored and influenced to support potential Manned Mars Missions A&R requirements.
- o Identify inflight training requirements and technology which exceeds that expected to be used on the Space Station.
- o Conduct a feasibility study of using the MEM flight hardware and software in a training mode for inflight landing and ascent training, and identify key technical questions.

#### REFERENCES

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